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U.S. PATENT APPLICATION

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Invention: FENOFIBRATE MICROPARTICLES

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SPECIFICATION

FENOFIBRATE MICROPARTICLES

This application is a continuation-in-part of application Serial No. 09/218,080 filed December 22, 1998 which is a continuation-in-part of application Serial No. 08/701,483 filed August 22, 1996, now U.S. 6,228,399. The disclosures of these applications are hereby incorporated by reference.

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This invention relates to compositions and procedures that yield sub-micron and micron stable particles of fenofibrate. The compositions of this invention include combinations of natural or synthetic phospholipids, and one or more nonionic, anionic or cationic surfactants coated or adhered onto the surfaces of the fenofibrate particles. The combination of phospholipids and surfactants allows the formation and stabilization of the sub-micron and micron size compound particles by modification of the surface and changes in hydrophilic, lipophilic and electrostatic interactions between particles.

BACKGROUND OF THE INVENTION

Fenofibrate is a prodrug that immediately after absorption is hydrolyzed by tissue and plasma esterases to its active major metabolite, fenofibric acid. Fenofibric acid is responsible for the pharmacological activity and its plasma half-life is about 20 hours. Fenofibrate is practically insoluble in water, it is poorly and variably absorbed and has to be taken with food.

Fenofibrate was first available in a pharmaceutical dosage form (Lipanthyl® also marketed under the trademarks Lipidil® and Lipantil®) consisting of a hard gelatin capsule containing fenofibrate, lactose, pregelatinized starch and magnesium stearate. After oral administration, during a meal, about 60% of the dose of this conventional form is effectively absorbed and found in the blood as fenofibric acid (Weil et al., The metabolism and disposition of 14C-fenofibrate in human volunteers, Drug. Metabol. Dispos. Biol. Fate. Chem., 18 (1990) 115-120).

Historically, in order to improve the intestinal absorption, another pharmaceutical dosage form was introduced (Lipanthyl® 67M and 200M, also

marketed under the trademarks Lipidil Micro®, Lipantil®Micro and Tricor™). European Patent Application 330,532 and U.S. patent 4,895,726 disclose a fenofibrate composition in which the fenofibrate powder is co-micronized with a solid wetting agent. Sodium lauryl sulfate is described as the wetting agent of choice. The co-micronized powder so obtained is mixed with capsule filling excipients such as lactose, starch, cross-linked polyvinyl pyrrolidone and magnesium stearate. A study comparing this formulation (Lipidil Micro®) to the conventional form (Lipidil®) had shown statistically significant increase in bioavailability with the former.

However, co-micronization of the active drug fenofibrate with the wetting agent sodium lauryl sulfate, although necessary, has several drawbacks such as irritation of mucosal membranes of the gastrointestinal tract. In addition, micronization is a time consuming and costly operation and the filling of hard gelatin capsules with a micronized powder is a difficult operation when taking into account the possibility of weight variation due to poor homogeneity.

European Patent Application 724,877 describes fenofibrate powder co-micronized with a wetting agent in association with a vitamin E component (tocopherol and/or its organic acid ester) for treating or preventing disorders associated with lipoprotein oxidation.

U.S. patent 4,800,079 relates to a medicinal composition in the form of granules with controlled release of fenofibrate. Each granule includes an inert core, a layer based on fenofibrate and a protective layer. Fenofibrate is present in the form of crystalline microparticles of dimensions not greater than 30 μm.

U.S. patent 4,961,890 relates to a process for preparing a controlled release formulation containing fenofibrate in an intermediate layer in the form of crystalline microparticles (< 30 μm in diameter) within a multilayer inert matrix.

U.S. patent 5,545,628 relates to a pharmaceutical composition for treating hyperlipidemia or hypercholesterolemia or both in a mammal, by providing an effective amount of each of fenofibrate and an excipient including one or more polyglycolyzed

glycerides (generally mixtures of known monoesters, diesters and triesters of glycerols and known monoesters and diesters of polyethylene glycols). The polyglycolyzed glycerides may be obtained by partial transesterification of triglycerides with polyethylene glycol or by esterification of glycerol and polyethylene glycol with fatty acids.

European Patent Application 757,911 relates to a fenofibrate pharmaceutical dosage form in which fenofibrate is in solution in diethylene glycol monoethyl ether (EMDG) which is a non ionic surfactant.

Current technology for delivering insoluble drugs as described in US Patents 5,091,188; 5,091,187 and 4,725,442 focuses on (a) either coating small drug particles with natural or synthetic phospholipids or (b) dissolving the drug in a suitable lipophilic carrier and forming an emulsion stabilized with natural or semisynthetic phospholipids. One of the disadvantages of these formulations is that certain drug particles in suspension tend to grow in size over time because of the dissolution and reprecipitation phenomenon known as the Ostwald ripening or particle growth. The solvent becomes saturated with solute, the larger particles grow at the expense of smaller particles which preferentially solubilize [Luckham, Pestic. Sci., (1999) **25**, 25-34].

As used herein, "micro" refers to a particle or collection of particles having diameter of from nanometers to micrometers. Microparticles, as used herein, refer to solid fenofibrate particles of irregular, non-spherical or spherical shapes with combinations of natural or synthetic phospholipids, and one or more nonionic, anionic or cationic surfactants coated or adhered onto the surfaces of the fenofibrate particles. Formulations containing these fenofibrate microparticles provide specific advantages over the unformulated, non-micronized, or "conventional" micronized particles, which include improved oral bioavailability as absorbed from the GI tract.

DESCRIPTION OF THE INVENTION

The present invention focuses on preparing submicron to micron size fenofibrate particles using a combination of surface modifier(s) with a phospholipid, and how the growth of particle size, and hence storage stability, is controlled by adding a combination of surface modifier(s) with a phospholipid to the formulation.

The use of a surface modifier or combination of surface modifiers in addition to a phospholipid is characterized by its ability to result in volume weighted mean particle size values that are (i) approximately 50% smaller than what can be achieved using phospholipid alone without the use of a surfactant with the same energy input, and (ii) provide compositions resistant to particle size growth on storage. While resistance to particle size growth on storage was an objective of this invention we were surprised to observe a significant reduction in particle size with the addition of the surfactant. In order to achieve the advantages of the present invention it is necessary that the phospholipid and the surfactant both be present at the time of particle size reduction or precipitation.

Another aspect of the present invention includes free-flowing powders of fenofibrate as well as solid dosage forms of these powders, for instance in the form of compressed tablets and the like. Surprisingly we have found that microparticulate formulations exhibit enhanced stability and bioavailability as illustrated in the data that follows.

Although we do not wish to be bound by any particular theory, it appears that these surface modifiers generally, that is phospholipids and one or more surfactants, adsorb to the surfaces of fenofibrate, and modify the surfaces to allow smaller particle formation and stailize the formed micoparticles. The concentrations of surface modifiers used in the process described here are normally above their critical micelle concentrations (CMC) and hence facilitate the formation of sub-micron to micron particles by stabilizing the particles.

Phospholipid and surface modifier(s) are adsorbed onto the fenofibrate particle surfaces in sufficient quantity to retard particle growth, reduce the initial average particle size of from 5 to 100 μm to micron and submicron size particles by one or combination of methods known in the art, such as sonication, homogenization, milling, microfluidization, precipitation or recrystallization or precipitation from supercritical fluid, and maintain sub-micron and micron size particles on subsequent storage as suspension or solid dosage form.

The concentration of phospholipid or surface modifier in the suspension or solid dosage form can be present in the range of 0.1 to 50%, preferably 0.2 to 20%, and more preferably 0.5 to 10%.

The formulations prepared by this invention may be dried, e.g., by lyophilization, fluid or spray drying, into powders, which can be resuspended or filled into capsules or converted into granules or tablets with the addition of binders and other excipients known in the art of tablet making.

The phospholipid may be any natural or synthetic phospholipid, for example phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine, phosphatidylinositol, phosphatidylglycerol, phosphatidic acid, lysophospholipids, sphyngomyelin, egg or soybean phospholipid or a combination thereof. The phospholipid may be salted or desalted, hydrogenated or partially or fully hydrogenated natural, semisynthetic or synthetic. Examples of commercially available phospholipids include but are not limited to egg phospholipids P123 (Pfanstiehl), Lipoid E80 (Lipoid); and hydrogenated soy phospholipids Phospholipon 90H and 100H (Natterman) and 99% pure soy or egg phosphatidyl choline (Avanti Polar Lipids).

Examples of some suitable surface modifiers include: (a) natural surfactants such as casein, gelatin, tragacanth, waxes, enteric resins, paraffin, acacia, gelatin, cholesterol esters and triglycerides, (b) nonionic surfactants such as polyoxyethylene fatty alcohol ethers, sorbitan fatty acid esters, polyoxyethylene fatty acid esters, sorbitan esters, glycerol monostearate, polyethylene glycols, cetyl alcohol, cetostearyl alcohol, stearyl

alcohol, poloxamers, polaxamines, methylcellulose, hydroxycellulose, hydroxy propylcellulose, hydroxy propylmethylcellulose, noncrystalline cellulose, polyvinyl alcohol, polyvinylpyrrolidone, and synthetic phospholipids, (c) anionic surfactants such as potassium laurate, triethanolamine stearate, sodium lauryl sulfate, alkyl polyoxyethylene sulfates, sodium alginate, dioctyl sodium sulfosuccinate, negatively charged phospholipids (phosphatidyl glycerol, phosphatidyl inositol, phosphatidylserine, phosphatidic acid and their salts), and negatively charged glyceryl esters, sodium carboxymethylcellulose, and calcium carboxymethylcellulose, (d) cationic surfactants such as quaternary ammonium compounds, benzalkonium chloride, cetyltrimethylammonium bromide, chitosans and lauryldimethylbenzylammonium chloride, (e) colloidal clays such as bentonite and veegum or a combination thereof. A detailed description of these surfactants may be found in Remington's Pharmaceutical Sciences, and Theory and Practice of Industrial Pharmacy, Lachman et al, 1986.

More specifically, examples of suitable surface modifiers include one or combination of the following surfactants: polaxomers, such as Pluronic™ F68, F108 and F127, which are block copolymers of ethylene oxide and propylene oxide available from BASF, and poloxamines, such as Tetronic™ 908 (T908), which is a tetrafunctional block copolymer derived from sequential addition of ethylene oxide and propylene oxide to ethylene-diamine available from BASF, Triton™ X-200, which is an alkyl aryl polyether sulfonate, available from Rohm and Haas. Tween 20, 40, 60 and 80, which are polyoxyethylene sorbitan fatty acid esters, available from ICI Specialty Chemicals, polyoxyethylene stearate (Myrj 52) available from ICI Specialty Chemicals, Carbowax™ 3550 and 934, which are polyethylene glycols available from Union Carbide, hydroxy propylmethylcellulose, dimyristoyl phosphatidylglycerol sodium salt, sodium dodecylsulfate, sodium deoxycholate, and cetyltrimethylammonium bromide. In some cases preferably at least two surfactants are used. In a preferred aspect of the invention, when free-flowing formulations are desired, the surfactant(s) will itself be a powder.

It is thought that some of the functions of the second surface modifier(s) as it relates to this invention are (a) allowing the formation of microparticles about 50% or smaller of the size produced with phospholipid alone, (b) suppressing the process of Ostwald Ripening and therefore maintaining the particle size, (c) increasing the storage stability, minimizing sedimentation, and decreasing the particle growth during lyophilization and reconstitution; (d) adhering or coating firmly onto the surfaces of water-insoluble drug particles and therefore modifying the interfaces between the particles and the liquid in the resulting formulations; (e) increasing the interface compatibility between water-insoluble drug particles and the liquid; and (f) possibly orienting preferentially themselves with the hydrophilic portion sticking into the aqueous solution and the lipophilic portion strongly adsorbed at the water-insoluble drug particle surfaces.

The most advantageous surface active agent for fenofibrate is illustrated in the examples that follow and/or as will be apparent following empirical tests to identify the surfactant or surfactant system/combination resulting in the requisite particle size and particle size stability on storage over time.

Various procedures can be used to produce these stable micron and sub-micron size fenofibrate particles including mixing the fenofibrate with phospholipid and surfactant(s) followed by sonication, milling, homogenization, microfluidization; or precipitating from a solution of the substance using antisolvent and solvent precipitation in the presence of the phospholipid and surfactant(s). Mannitol and other agents may be added to adjust the final formulation to isotonicity as well as acting as a stabilizing aid during drying.

Unless otherwise specified, all parts and percentages reported herein are weight per unit volume (w/v), in which the volume in the denominator represents the total volume of the system. Diameters of dimensions are given in millimeters (mm = 10^{-3} meters), micrometers (μm = 10^{-6} meters), nanometers (nm = 10^{-9} meters) or Angstrom units (= 0.1 nm). Volumes are given in liters (L), milliliters (mL = 10^{-3} L) and

microliters ($\mu L = 10^{-6}L$). Dilutions are by volume. All temperatures are reported in degrees Celsius. The compositions of the invention can comprise, consist essentially of or consist of the materials set forth and the process or method can comprise, consist essentially of or consist of the steps set forth with such materials. The following examples further explain and illustrate the invention:

The following microparticle-fenofibrate formulations were prepared either by using Microfluidizer® model 110EH (Microfluidics Corp., Newton, MA) or Avestin model C5 (Ottawa, Canada).

A premix of the formulation was prepared by placing the ingredients in an appropriate size vessel with the required amount of water and mixed with a hand held homogenizer. The premix so formed was then placed in the inlet reservoir of the homogenizer and passing the outlet flow through a thermostatically controlled cooler to control the inlet temperature. The premix was then pumped through the homogenizer at 18,000-20,000 psi. The homogenization process can either be done by discrete passes or in continuous mode. For the sake of comparison, all formulations (except Example 2) were homogenized for 90 passes in Avestin homogenizer. The formulation in example 2 was prepared in a Microfluidizer® with using approximately 50 passes at full pressure. The formulations were harvested and particle size and other parameters measured. The particle size determination was performed with Malvern Mastersizer model Micro-Plus (Southborough, MA). The particle size data are presented as volume weighted mean particle size.

The composition and concentration of excipients of various microparticle fenofibrate formulations are listed below. The amount of excipients used is expressed as percent (w/w):

Example 1

Fenofibrate	10.0
Phospholipon 100H	2.0
Tween 80	2.0
Mannitol	5.5
Mean particle size:	0.85 μm

Example 2

Fenofibrate	10.0
Phospholipon 100H	2.0
Tween 80	2.0
Mannitol	10.0
Mean particle size:	1.02 μm

Example 3

Fenofibrate	10.0
Phospholipon 100H	2.0
PVP 30	1.5
Mannitol	5.5
Mean particle size:	1.28 μm

Example 4

Fenofibrate	10.0
Phospholipon 100H	2.0
Myrj 52	1.5
Mannitol	5.5
Mean particle size:	1.21 μm

Example 5

Fenofibrate	10.0
Phospholipon 100H	2.0
Poloxamer 188	1.5
Mannitol	5.5
Mean particle size:	1.12 μm

Example A

For the purpose of comparison (not according to the invention) using only a phospholipid, (without the second surface modifier, Tween 80), fenofibrate particles were also prepared using the same procedure as Example 1:

Fenofibrate	10.0
Phospholipon 100H	2.0
Mannitol	5.5
Mean particle size:	3.17 μm

A comparison of the resulting mean particles size of the final formulations in Examples 1 to 5, inclusive, with Example A demonstrate the effect of adding the second surface modifier on the final particle size. Also, it was observed that the use of a second surface modifier helps to eliminate the thick slurry produced when Phospholipon 100H is used alone as in Example A.

Example 6: Oral bioavailability of fenofibrate microparticles in human subjects.

The Fenofibrate composition used in Example 2 was tested in a human volunteers study. The study consisted of oral administration of the fenofibrate formulation to eight human volunteers in a single dose crossover design, using the marketed formulation as a reference. The dose administered was 67 mg. Blood samples were collected before and after each administration at various time points over 120 hours.

The drug concentration in blood samples was determined by high-pressure liquid chromatography by monitoring for the level of the metabolite, fenofibric acid. The pharmacokinetic results are presented in Table 1 and demonstrate the superior bioavailability of the fenofibrate formulation over the commercially available product.

Table 1.

C_{max} and $AUC_{0\text{-}inf}$ for Fenofibric Acid

	C_{max} ($ng.ml^{-1}$)	$AUC_{0\text{-}inf}$ ($ng.ml^{-1}.h$)
Fenofibrate microparticles (67 mg)	2528	57235
Commercially available fenofibrate (67 mg) product	1372	38629
Dunnett's t-test (log transformed data)	$p<0.05$	$p<0.05$